REMARKS

This amendment responds to the office action mailed on October 1, 2001. In the office action the Examiner:

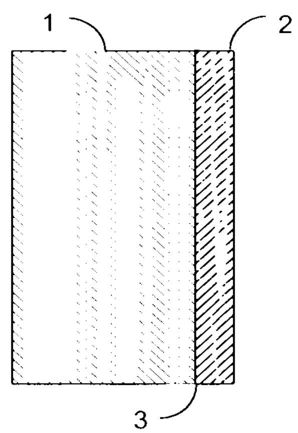
- rejected claims 12-18 and 39-51 under 35 U.S.C. 112, first paragraph, as based on a disclosure which is not enabling;
- rejected claims 1-18 and 39-51 under 35 U.S.C. 112, second paragraph, as indefinite;
- rejected claims 1, 3-5, 28, 29, 33 and 34 under 35 U.S.C. 103(a) as being unpatentable over Char *et al.* (5,157,466);
- rejected claims 2, 30 and 31 under 35 U.S.C. 103(a) as being unpatentable over Char *et al.* (5,157,466) in view of Shnirman *et al.* (Physical Review B 57, p. 15400, 1998);
- rejected claims 6, 8-10, 35, 39, 40 and 41 under 35 U.S.C. 103(a) as being unpatentable over Char *et al.* in view of Baechtold *et al.* (3,953,749); and
- rejected claims 7, 11 and 12-18, 36, 37, 42, 43, 45, 46 and 48-50 under 35 U.S.C. 103(a) as being unpatentable over Char *et al.* in view of Baechtold *et al.* and further in view of Shnirman *et al.*

After entry of this amendment, the pending claims are claims 1-18 and 28-65.

New claims 52-55 are directed to qubits wherein each quantum state of the qubit is characterized by a clockwise or a counterclockwise circulating supercurrent. New claims 56-59 are directed to qubits that are twice degenerate in the absence of an external electromagnetic field. New claim 60 and dependent claims 61 and 62 are for qubits that include circuitry to allow interruption of the quantum tunneling between the ground states of the supercurrent. New claim 63 is for a quantum computer that includes a qubit and a readout device. New claim 64 is for a quantum register that includes circuitry to allow interruption of the quantum tunneling between the ground states of the supercurrent, and new claim 65 is for a quantum computer that includes a quantum register and a readout device.

The Invention

Before addressing the specific rejections, an overview of some aspects of the present invention is in order. Applicant has discovered a novel device, termed a quantum coherer, that may be used for quantum computing. The quantum coherer is a special form of qubit. A qubit is a system having two degenerate quantum states. In some embodiments of the present invention, the quantum coherer comprises a clean Josephson junction between a large "bank" (1) and a mesosopic island (2). The bank and island are made of superconducting material such as a d-wave superconductor. An example of a d-wave superconducter is $YBa_2Cu_3O_{7-\delta}$. Key features of the quantum coherer are illustrated below:



The illustrated quantum coherer has properties A through D:

A. (2) is joined to (1) by a clean Josephson junction (3);

B. the quantum coherer is operated at superconducting temperatures;

C. (2) is mesoscopic; and

D. (1) and (2) may have different crystallographic orientations.

When the quantum coherer has these properties, the phase of the superconducting current in (2) has a nonzero probability of being in two degenerate quantum states, denoted "$+\varphi$" and "$-\varphi$". If (2) was not mesoscopic, then the phase of the superconducting current in (2) would no longer have a nonzero probability of being in two degenerate quantum states. Rather, the phase of the superconducting current would adopt a constant value. The specification describes a number of devices that include one or more quantum coherers.

Generally, in order for (2) to be mesoscopic, it must have dimensions that are in the low micrometer range or smaller. These dimensions are necessary because the mesoscopic island (2) must be sensitive to the introduction of even one Cooper pair of electrons from (1). If (2) were to adopt larger dimensions, such as those found in Char *et al.*, (2) would no longer be sensitive to the introduction of a Cooper pair of electrons from (1). The determination of whether (2) is sensitive to the entry of Cooper pairs is realized by the phase of the superconducting current in (2). If (2) is mesoscopic, then the phase of the superconducting current in (2) has a nonzero probability of being in two degenerate quantum states. If (2) is too large to be mesoscopic, then the phase of the superconducting current in (2) adopts a constant value and cannot support quantum computing.

The quantum state of (2) can be measured using techniques such as collapsing and freezing. Multiple quantum coherers can be combined to form a register that can then be used for quantum computing. Applicant additionally provides novel circuitry that, for example, uses Single-Electron Transistors (SETs) to aid in performing quantum computing operations.

<u>Rejection of Claims 12-18 and 39-51 Under 35 U.S.C. 112, First Paragraph</u>

Claims 12-18 and claims 39-51 have been rejected under 35 U.S.C. 112, First Paragraph, because the Examiner contends that these claims recite structure in a register without adequate support in the specification to state how such structure could be part of a functional register. In particular, the Examiner points out that claim 12 recites a quantum register comprising a first plurality of single-electron transistors (SETs), claim 14 recites a quantum register having a Josephson junction between a first and second bank, and claim 15 recites a quantum register comprising a SETs that are coupled between a bank and corresponding islands. The Examiner points out that claims 16, 17, 18, and 39-51 recite similar structure.

The rejection of claims 12-18 and claims 39-51 is respectfully traversed. Applicant would first like to respectfully point out that claims 12-18 and claims 39-51 recite a "quantum register," as opposed to a general purpose "register." Applicant's reference to shift registers

in the August 7, 2001 response was not intended to imply that a quantum register is a shift register or that the quantum register recited in the pending claims is in any way a shift register. Applicant sought to merely point out to the Examiner that conventional registers that perform operations on the stored quantity are well known in the art.

The term "quantum register" is well known to those of ordinary skill in the art to mean a well defined physical system used for storing and processing quantum information. The term is widely used in this fashion in numerous publications and texts, *e.g.* **Schön** *et al.*, "Josephson-Junction Qubits and the Readout Process by Single/Electron Transistors," arXiv:cond-mat/9811029 v1 2 Dec. 1999 ("For quantum computation a register, consisting of a (large) number of qubits is needed...", p.4); Duan *et al.*, "Decoherence of Quantum registers," arXiv:quant-ph/9703036 v1 20 Mar. 1997 (We consider decoherence of quantum registers, which consist of the qubits sited approximately periodically in space." Abstract); Zanadrdii, "Dissipative Dynamics in a Quantum Register," arXiv:quant-ph/9708042 vl 25 Aug 1997 ("The register consists of N qubits . . ."). The term quantum register, as utilized in the present application, continues to be used in this fashion. *See*, *e.g.*, MIKA HIRVENSALO, QUANTUM COMPUTING, p. 26 (Springer, 2001) ("By a *quantum register* of the length *m* we understand an ordered system of *m* qubits.").

Under the normal use of the term "quantum register," as recited in claims 1-18 and 28-51, a quantum register is an array of qubits. A qubit is conventionally a system having two degenerate quantum states, and the initial state of the qubit typically has non-zero probabilities of being found in both degenerate quantum states. Quantum registers are illustrated in Figures 7 and 8 as qubits 120-1 through 120-N. The quantum register does not necessarily include devices for readout of quantum states stored on the individual qubits or for entangling quantum states between qubits or for otherwise manipulating quantum states stored on the qubits of the quantum register, for example, single-electron transistors (SETs) or parity keys. Accordingly, the specification fully enables a quantum register having the structure recited in claims 1-18 and 28-51.

For the above identified reasons, Applicant requests that the 35 U.S.C. § 112, First Paragraph, rejection of claims 12-18 and claims 39-51 be withdrawn.

Rejection of Claims Under 35 U.S.C. § 112, Second Paragraph

The Examiner has rejected claims 1-18 and 39-51 under 35 U.S.C. § 112, second paragraph, for three reasons. First, the Examiner contends that it is not clear how the devices recited in claims 12 and 14 as well as claims 39-51 could function as a register or how the recited SETs are fabricated, designed, or function. Second, the Examiner contends that the parity key recited in claims 32, 38, 44, 47 and 51 is not defined. Third, the Examiner contends that the term "mesoscopic" is not understood. Applicant respectfully traverses these rejections and addresses each of them in turn.

The registers recited in claims 12 and 14 as well as claims 39-51.

As in the case of the 35 U.S.C. § 112, first paragraph, rejections, Applicant respectfully points out that claims 12 and 14 and claims 39-51 recite a "quantum register" as opposed to a general purpose "register." A discussion on the metes and bounds of the term "quantum register" is found in the discussion of the 35 U.S.C. § 112, first paragraph, rejections above.

***Single-Electron Transistors* (SETs)**

The specification discloses quantum registers that include SETs. See, for example, Figures 7 and 8 of the specification as well as pages 16 through 18 of the specification.

The fabrication, design, and function of SETs is well known in the art, as evidenced by the large number of publications addressing such aspects relating to SETs. See, for example, Joyez *et al.*, 1994, Observation of Parity-Induced Suppression of Josephson Tunneling in the Superconducting Single Electron Transistor, *Phys. Rev. Lett.* 72, pp. 2458-2461, which is incorporated by reference in its entirety on page 15 of the specification. SETs are also discussed in ZAGOSKIN, "QUANTUM THEORY OF MANY-BODY PROCESSES" ("ZAGOSKIN"), p. 203, which was incorporated by reference in its entirety on page 15 of the specification of the current application.

As described in Joyez *et al.*,

> The consequences of the duality of phase and number-of-particle variables are particularly well illustrated by the competition between Josephson tunneling and single electron charging phenomena in ultrasmall superconducting junction systems. One of the simplest devices consists of two Josephson junctions in series: The number of Cooper pairs on the middle "island" tends to be fixed by the Josephson charging energy $E_C=e^2/2C$ of the island while the associated phase tends to be fixed by the Josephson coupling energy E_J of the two junctions which we suppose are identical for simplicity.
> ... for small area junctions ($E_J << E_C$), the maximum supercurrent should strongly depend on the polarization charge Q_g applied to the island by means of a gate electrode, hence the name of "**superconducting single electron transistor**" given to such a device.

Joyez *et al.*, p. 2458 (references omitted) (emphasis added).

The SETs claimed in the present application are formed with Josephson junctions and therefore are superconducting. The specification has been amended to include this information by copying text from Joyez *et al.* at p. 2458 into page 15 of the specification. Joyez *et al.* also discusses the fabrication of a SET. The specification has been amended to include this information as well.

SETs as described in the present application can operate as switches to connect, for example, qubits to ground, qubits to other qubits, or qubits to other control devices. When a voltage is capacitively applied to the center island of the SET, supercurrent is allowed to flow through the Josephson junctions of the SET. If no voltage is applied, electrostatic interactions on the center island prevent current flow through the junctions.

The term SET is well utilized in the art, as observed by its use in a large number of publications addressing aspects of SETs. For example, Averin *et al.*, 1977, *Phys. Rev. Lett.* 78, pp. 4821 ("The aim of this work is to study the quasiparticle transport in a superconducting single electron transistor (SET)); Hanke *et al.*, 1995, *Phys. Rev. B* 51, p. 9084 ("A microscopic theory has been constructed to investigate tunneling current and shot noise in a normal-superconductor-normal (NSN) single-electron transistor (SET).").

PARITY KEYS

As described in ZAGOSKIN, *Id.*, parity keys are a variation of SETs where odd electrons are detected:

> If the grain becomes superconducting, there appear interesting new possibilities. As we know, in the ground state of a superconductor all electrons are bound in Cooper pairs (and therefore the ground state can contain only an even number of electrons). An odd electron will thus occupy an excited state, as a bogolon, and its minimum energy, measured from the ground state energy, will be Δ.
>
> This is the *parity effect* in superconductivity. Of course, in a bulk superconductor it is of not importance, but not so in our small system, where charging effects enter the game.

ZAGOSKIN, p. 206.

MESOSCOPIC

Before discussing the term mesoscopic, as defined in the specification and in the literature, a few introductory remarks are warranted. Page 9, lines 15-17, provides that "[t]he two states associated with the supercurrent in island 120 permit quantum computing as described further below." The two states referred to in the quoted passage are the two degenerate states for the phase of the supercurrent in island 120 (Fig. 1). Importantly, island 120 will not have two degenerate quantum states unless it is mesoscopic.

The phase of supercurrent in a mesoscopic island within the quantum coherer of the present invention has two degenerate states. Further, it is not possible for the phase of the supercurrent in the mesoscopic island to remain constant as current moves through the Josephson junction. This is because the mesoscopic island is sensitive to the number of electrons within the island. For this reason, there is a nonzero probability that the phase of the superconducting current within the mesoscopic island is in two degenerate states, denoted "$+\varphi$" and "$-\varphi$". If the island was not mesoscopic in that is had larger dimensions, the island would no longer be sensitive to the number of electrons within the island and the phase of the supercurrent within the mesoscopic island would adopt a constant value. Thus, for large non-

mesoscopic islands (banks or regions), the feature of having a superconducting current that has a nonzero probability of being in two degenerate quantum states, in the absence of any external force, is not possible. Thus, as used throughout the specification, a mesoscopic island is an island which, in the context of a quantum coherer, is capable of supporting a superconducting current with a phase that has a nonzero probability of being in one of two degenerate states. In order to support such a current, the mesoscopic island must have dimensions that make the island sensitive to the number of electrons within the island. Such dimensions will vary depending upon the exact configuration of the quantum coherer, but are generally within the micrometer range, as taught in the specification.

The term mesoscopic is a well used term in the field of physics and, in general, indicates a device of physical dimension such that phenomena observed on the structure require quantum mechanical explanation. In other words,

> there exists a class of solid systems where the single particle approach holds and gives sensible results, namely, the *mesoscopic systems* (see, e.g., **Imry 1986**). These are the systems of intermediate size, i.e., macroscopic but small enough (10^{-4} cm). In these systems quantum interference is very important, since at low enough temperatures (< 1K) the phase coherence length of quasiparticles ("electrons") exceeds the size of the system.

Zagoskin, *Quantum Theory of Many-Body Systems*, pp. 19-20 (Springer, 1998), citing Y. Imry, "Physics of Mesoscopic Systems", in *Directions in Condensed Matter Physics: Memorial Volume in Honor of Shang-Keng Ma* (Grinstein and Mazenko, eds., World Scientific, 1986). Since Zagoskin is incorporated by reference in the application (see page 19, the specification on page 8 has been amended to include this definition of mesoscopic.

The term *mesoscopic* is widely used in texts and in literature to refer to a class of structure of physical size such that the phase coherence length of particles are greater than the physical dimension of the system. If the condition is not met, then the quantum states will not be supported by a qubit.

One popular web site dictionary, at the URL http://physics.about.com, defines mesoscopic as follows: "Designating a size scale intermediate between those of the microscopic and the macroscopic. Mesoscopic objects and systems require quantum mechanics to describe them."

Entire fields of physics are devoted to the study of mesoscopic systems. The Los Alamos National Laboratory, a leading electronic database of preprints of scientific articles, accessed through www.ArXiv.org, includes an entire subject class entitled "Mesoscopic Systems and Quantum Hall Effect." The term is found utilized in hundreds of papers in many sub-disciplines of physics both in and out of the field of superconducting devices.

THE MCGRAW-HILL ENCYCLOPEDIA OF SCIENCE & TECHNOLOGY (8th ed. 1997) includes a section on mesoscopic physics, which is attached to this Response. The McGraw-Hill definition of mesoscopic physics is

> [a] subdiscipline of condensed-matter physics that focuses on the properties of solids in a size range intermediate between bulk matter and individual atoms or molecules. The size scale of interest is determined by the appearance of novel physical phenomena absent in bulk solids and has no rigid definition; however, the systems studied are normally in the range of 100 nanometers (10^{-7} meters, the size of a typical virus) to 1000 nm (the size of a typical bacterium). Other branches of science, such as chemistry and molecular biology, also deal with objects in this size range, but mesoscopic physics has dealt primarily with artificial structures of metal or semiconducting material which have been fabricated by the techniques employed for producing microelectronic circuits. Thus it has a close connection to the fields of nanofabrication and nanotechnology. The boundaries of this field are not sharp; nonetheless, its emergence as a distinct area of investigation was stimulated by the discovery of three categories of new phenomena in such systems: interference effects, quantum size effects, and charging effects.

MCGRAW-HILL ENCYCLOPEDIA OF SCIENCE & TECHNOLOGY, vol. 10, p. 722 (8th ed. 1997).

Systems of structural size of about 10^{-6} meters or less, at low enough temperatures, have a physical size smaller than the phase coherence length of charges in the structure and therefore are mesoscopic structures. Therefore, far from being undefined, the term mesoscopic has a definite meaning and imposes a definite restriction on the size of structures described as mesoscopic.

For the above identified reasons, Applicant requests that the 35 U.S.C. 112, Second Paragraph, rejection of claims 1-18 and 39-51 be withdrawn.

Rejection of Claims Under 35 U.S.C. 103(a) Over Char *et al.*

The Examiner has rejected claims 1, 3-5, 28, 29, 33 and 34. This rejection is respectfully traversed. Char *et al.* teaches a grain boundary formed on a planar substrate by depositing superconducting film onto the substrate in such a way that the film adopts different crystal orientations in two sections of the crystallized film. The boundary between the two sections is the grain boundary. However, Char *et al.* does not teach or suggest a device in which one section is mesocopic. For this reason, Char *et al.* does not teach or suggest a device capable of performing quantum computing. Thus, claims 1 and 28 are patentable over Char *et al.*

As previously noted, the term "mesoscopic" is well understood in the art and refers to dimensions that are so small that the superconducting material having such dimensions has a superconducting current with a phase that has a nonzero probability of being in two degenerate quantum states. The Examiner reasons that the devices of Char *et al.* could be made arbitrarily small such that one of the sections of the device of Char *et al.* could become mesoscopic. (Final Office Action, page 5, paragraph 4). This is not the case. The techniques used to build the devices of Char *et al.* are designed for the preparation of bulk devices (*i.e.* devices having dimensions that are too large to support or include a mesoscopic island). Furthermore, Applicant respectfully points out that Char *et al.* provides no motivation to make the devices of Char *et al.* arbitrarily small.

Many manufacturing obstacles must be overcome in order to produce the quantum computing structure of claim 1 or the qubit of claim 28. For example, faceting (wobble) at the junction between the two sections must be minimized in order to support the two

degenerate states in the mesoscopic island. This leads to the requirement of a clean Josephson junction separating the island and bulk regions of the present invention. Faceting refers to irregularities in the junction between two sections (*i.e.* the clean Josephson junction between the first bank of superconducting material and the mesoscopic island of claim 1) that arises using conventional manufacturing techniques. Put simply, the methods used by Char *et al.* do not overcome the many obstacles necessary to build a device that is capable of quantum computing. In particular, the methods used by Char *et al.* cannot achieve a mesoscopic device in which the phase of a superconducting current in the device has a nonzero probability of being in two degenerate quantum states.

One difficulty in designing the claimed apparatus is the development of a first bank of a superconducting material having a first crystal orientation and a mesoscopic island of a superconducting material having a second crystal orientation, wherein a clean Josephson junction forms between the bank and the island. Applicant has overcome some of these manufacturing issues by using a bi-crystal substrate. Specification at page 8, lines 5-6). In Char *et al.*, a seed layer determines the crystallographic orientation of the substrate that is grown on the seed layer. To produce two banks of material on a substrate that have different crystallographic orientations, Char *et al.* makes use of one or more seed layers (bi-epitaxial technology). However, the use of one or more seed layers as disclosed in Char *et al.* is problematic. In particular, the junction between banks grown using the methods of Char *et al.* has too much faceting and therefore is not capable of quantum computing.

As described above, the methods of Char *et al.* use bi-epitaxial technology to produce bulk devices. Current research in the art has focused on issues related to achieving high quality Josephson junctions using bi-epitaxial technology. For example, Nicoletti *et al.*, 1996, Physica C 290, pp. 255-267, describe techniques for bi-epitaxial fabrication more advanced than those described by Char *et al.* A courtesy copy of Nicoletti is attached hereto as Appendix D. Figure 8 on page 265 illustrates the properties of a bi-crystal Josephson junction compared with a bi-epitaxial Josephson junction, and concludes that the bi-epitaxial Josephson junction exhibits a "diffraction pattern that largely deviates from the expected behavior." (page 266, paragraph 2, line 13). This indicates that the bi-epitaxial method is problematic. For instance, faceting is a problem. Contrary to the Examiner's suggestions,

Char *et al.* does not teach or suggest the claimed invention and the methods of Char *et al.* cannot be used to make the claimed device.

Claims 3-5 depend from claim 1, and therefore have all the limitations of claim 1. Claims 29, 33, and 34 depend from claim 28 and therefore have all the limitations of claim 28. Therefore, claims 3-5 and 29, 33, and 34 are allowable for the same reasons that claims 1 and 28 are allowable. Applicant respectfully requests that the rejection be withdrawn.

Rejection of Claims Under 35 U.S.C. 103(a) Over Char *et al.* in View of Shnirman *et al.*

The Examiner has rejected claims 2, 30 and 31 on the basis that Shnirman *et al.* shows the use of a SET to read out a JJ q-bit. Claim 2 depends from claim 1 and claims 30 and 31 depend from claim 28. Accordingly, these claims are patentable over Char *et al.* for the same reasons that claims 1 and 30 and 31 are patentable over Char *et al.* Shnirman *et al.* does not remedy Char *et al.*

In addition, claims 2, 30, and 31 are patentable over the combination of the teachings of Char *et al.* and Shnirman *et al.* because, contrary to the teachings of Shnirman *et al.*, the devices recited in claims 2, 30 and 31 are not readout devices. Rather, the devices recited in claims 2, 30 and 31 connect a mesoscopic island to ground. The specification teaches that a SET connected between the mesoscopic island of a qubit and ground, as recited in claims 2 and 31, is used to collapse the wavefunction in the qubit so that the supercurrent at the Josephson junction in the qubit has a definite magnetic moment (specification page 17, lines 11-13). Then, the magnitude of the magnetic moment is read out using, for example, a magnetic force microscope, superconducting quantum interference device, or the detection of a difference in the absorption of circularly polarized microwave radiation due to the clockwise or counterclockwise currents at the Josephson junction. The SET is not used to perform the readout.

Furthermore, Shnirman *et al.* does not disclose a quantum computing structure or qubit that includes a mesoscopic island and a clean Josephson junction. Rather, Shnirman *et al.* discloses a charge qubit that is capable of supporting dual degenerate states by the use of an external electrical voltage that is applied to the charge qubit. Claims 1 and 28 of the instant application do not require the application of an external electrical voltage in order to

support dual degenerate states. For these reasons, claims 2, 30 and 31 are patentable over Shnirman *et al.* Accordingly, Applicant respectfully request that the rejection be withdrawn.

New claims 56-59 are patentable over Char *et al.* in view of Shnirman *et al.* for the additional reason that they recite a phase qubit (*i.e.* a qubit in which the quantum states are values of the phase of the mesoscopic island), wherein the quantum states of the qubits recited in claims 56-59 have natural degeneracy. In contrast, Shnirman *et al.* discloses a charge qubit where the quantum states in a charge qubit are the non-degenerate states corresponding to the quantized charge on the device. In order for the device of Shnirman *et al.* to function as a qubit, an external electric field must be applied to achieve degeneracy between the quantum states of the device. The qubits of claims 56-59 have an advantage over the charge qubits of Shnirman *et al.* in that they have built in degeneracy, whereas the charge qubits of Shnirman *et al.* have to shift the operating point of the device (for instance by changing an external electrical field).

<u>Rejection of Claims Under 35 U.S.C. 103(a) Over Char *et al.* in View of Baechtold *et al.*</u>

The rejection of claims 6, 8-10, 35, 39, 40 and 41 is respectfully traversed. Claims 6, 8-10 and 35 depend from claims 1 and 28. Claim 39 recites a mesoscopic island and claims 40 and 41 depend from claim 39. Char *et al.* does not teach or suggest a mesoscopic island (i.e. a superconducting bank in which the phase of the superconducting current has a nonzero probability of being in one of two degenerate states) as recited in claims 1, 28, and 39. Baechtold *et al.* does not remedy the deficiency of Char *et al.* Therefore, claims 6, 8-10, 35, 39, 40 and 41 are patentable over the combination of Char *et al.* and Baechtold *et al.*

As an additional matter, Baechtold *et al.* discloses two Josephson junctions connected in series in which each Josephson junction is bridged by a load impedance. In Baechtold *et al.*, the feed voltage is set so that one of the Josephson junctions is in a voltage state, and the other is in a superconducting state. See Baechtold *et al.*, Abstract, lines 1-9. In contrast, claim 6 specifies a Josephson junction (see 130-1 in Fig. 8) between a first bank (see 110) and a mesoscopic island (see 120-1), and a Josephson junction (see 830) between a first bank (see 110) and a second bank (see 810 in Fig. 8). The Josephson junctions in claim 6 of the present invention are not connected in series, as Baechtold *et al.* discloses; instead, the

Josephson junctions specified in claim 6 share the same first bank of superconducting material. Therefore, claim 6 is allowable. Claim 35 has limitations that are similar to claim 6, and therefore claim 35 is allowable for the same reasons that claim 6 is allowable.

Claim 8 specifies a quantum register comprising a clean Josephson junction between a bank and corresponding mesoscopic islands. Once again, the Josephson junctions in claim 8 are not connected in series, as Baechtold *et al.* teaches; instead, the Josephson junctions specified in claim 8 share the same bank of superconducting material. Claims 9-10 are dependent on claim 8 and are allowable for the same reasons that claim 8 is allowable. Claim 39-41 have limitations that are similar to claims 8-10, and therefore claims 39-41 are allowable for the same reasons that claims 8-10 are allowable.

Rejection of Claims Under 35 U.S.C. 103(a) Over Char in View of Shnirman and Baechtold

The rejection of claims 7, 11 and 12-18, 36, 37, 42, 43, 45, 46 and 48-50 is respectfully traversed. All of the rejected claims require a mesoscopic island connected to a first bank of superconducting material by a clean Josephson junction. Char *et al.*, Shnirman *et al.*, and Baechtold *et al.* do not teach or suggest a mesoscopic island connected to a first bank of superconducting material by a clean Josephson junction nor do they teach or suggest methods for manufacturing such a device. Therefore claims 7, 11 and 12-18, 36, 37, 42, 43, 45, 46 and 48-50 are patentable over the combination of Char *et al.*, Shnirman *et al.*, and Baechtold *et al.*

Furthermore, contrary to the Examiners assertions (Final office action, page 4, point 21) claims 7, 11, 36, 37 and 43 do not recite a readout for the claimed device. Rather, the devices recited in these claims are used, for example, to collapse the wavefunction in a qubit so that the supercurrent at the Josephson junction in the qubit has a definite magnetic moment (specification page 17, lines 11-13).

In light of the above remarks, the Applicant respectfully requests that the Examiner reconsider this application with a view towards allowance. The Examiner is invited to call the undersigned attorney if a telephone call could help resolve any remaining items.

Respectfully submitted,

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APPENDIX A

Changes to the specification

On page 8, between lines 2 and 3, the following paragraph is added:

The term mesoscopic, in general, refers to

> a class of solid systems where the single particle approach holds and gives sensible results, namely, the *mesoscopic systems* (see, e.g., **Imry 1986**). These are systems of intermediate size, i.e., macroscopic but small enough (10^{-4} cm). In these systems quantum interference is very important, since at low enough temperatures (< 1K) the phase coherence length of quasiparticles ("electrons") exceeds the size of the system. This means that the electrons preserve their "individuality" when passing through the system.
>
> Since the wave function of the quantum particle depends on its energy as e^{-iEt}, any inelastic interaction spoils the phase coherence. Then the condition
>
> $$l_\varphi \quad l_i < L \qquad [sic] \qquad (1.53)$$
>
> must hold. Here l_φ is the phase coherence length, l_i is the inelastic scattering length, L is the size of the system. The above condition can be satisfied in experiment, due to the fact we have discussed above: that in the condensed matter we can deal with weakly interacting quasiparticles instead of strongly interacting real particles.
>
> Because the inelastic scattering length of the quasielectron exceeds the size of the mesoscopic system, we can regard it as a single particle in the external potential field and apply to it the path integral formalism in the simplest possible version.

ALEXANDER M. ZAGOSKIN, QUANTUM THEORY OF MANY-BODY SYSTEMS p. 19-20 (Springer 1998), citing Y. Imry, "Physics of Mesoscopic Systems," in DIRECTIONS IN CONDENSED MATTER PHYSICS: MEMORIAL VOLUME IN HONOR OF SHANG-KENG MA (ed. G. Grinstein, G. Mazenko, World Scientific 1986).

On page 15, between lines 16 and 17, please place the following paragraph:

Joyez *et al.*, Observation of Parity-Induced Suppression of Josephson Tunneling in the Superconducting Single Electron Transistor, *Phys. Rev. Lett.* 72, pp. 2458-2461,

provide a complete description of the operation of a superconducting single electron transistor (SET). Joyez *et al.* states that:

> The consequences of the duality of phase and number-of-particle variables are particularly well illustrated by the competition between Josephson tunneling and single electron charging phenomena in ultrasmall superconducting junction systems. One of the simplest devices consists of two Josephson junctions in series: The number of Cooper pairs on the middle "island" tends to be fixed by the charging energy $E_c=e^2/2C$ of the island while the associated phase tends to be fixed by the Josephson coupling energy E_J of the two junctions which we suppose identical for simplicity. Here C refers to the total capacitance of the island. This model system has been investigated theoretically in detail. For large area junctions ($E_J>>E_C$) the charging effects are overcome by Josephson tunneling and the maximum supercurrent that can flow through the two junction system is just $I_o=2eE_J/$, the maximum supercurrent of each junction. However, for small area junctions ($E_J<< E_C$), the maximum supercurrent should strongly depend on the polarization charge Q_g applied to the island by means of a gate electrode, hence the name of "superconducting single electron transistor" given to such a device.

(Joyez *et al.*, p. 2458). Further, Joyez *et al.* describe fabrication of a SET:

> The sample was prepared using standard e-beam lithography and shadow mask evaporation techniques. The main difference with previous experiments is the use of the three-angle evaporation technique of Haviland *et al.*, J. Phys. B 85, 339 (1991) in order to fabricate in a single pump down the alumina-covered Al island electrode, the two Al drain and source electrodes, and the Cu (3 wt.% Al) buffer electrodes.

(Joyez *et al.*, p. 2458) (citation added). With regard to Parity Keys, ZAGOSKIN, p. 206, describes the parity effect in the following passage:

> If the grain becomes superconducting, there appear interesting new possibilities. As we know, in the ground state of a superconductor all electrons are bound in Cooper pairs (and therefore the ground state can contain only an even number of electrons). Any odd electron will thus occupy an excited state, as a bogolon, and its minimum energy, measured from the ground state energy, will be Δ.
>
> This is the parity effect in superconductivity. Of course, in a bulk superconductor it is of no importance, but not so in our small system, where charging effects enter the game.

APPENDIX B

Changes to the Claims

The rewritten claims were revised as follows:

39. (Amended) A quantum register, comprising:

a first bank of superconducting material;

at least one mesoscopic island of a superconducting material; <u>and</u>

<u>at least one</u> Josephson junction [junctions]<u>, each Josephson junction in said at least one Josephson junction</u> formed between [each of the] <u>a mesoscopic island in the</u> at least one mesoscopic island and the <u>first</u> bank.

APPENDIX D

Courtesy copy of Nicoletti *et al.* Physica C 269 (1996), p. 255-267